Dosimetric comparison of radioactive bone cements for the treatment of spinal metastases

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JULY 12–16 2020 VIRTUAL
Improving Health QUALITY. Increasing Global IMPACT
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EASTERN TIME [GMT-4]

INTRODUCTION

Radiation therapy plays an essential role in the treatment of spinal metastases. In external beam radiation therapy, the radiation tolerance of the spinal cord limits the allowable dose to be delivered to the vertebral body. Brachytherapy has the advantage of sparing spinal cord by implanting radioactive seeds or beta-emitting plaques adjacent to the tumor [1]. In the case of spinal fracture and deformity percutaneous vertebroplasty is performed. It involves the injection of bone cement into the collapsed vertebral body through a needle to maintain spine stability and to relieve the pain [2]. The radioactive bone cement loaded by a uniformly distributed beta-emitting radioisotope was presented to suppress the tumor growth in the vertebral body [3]. The combination of vertebroplasty and brachytherapy was introduced as a minimally invasive method to overcome spine instability and tumor growth simultaneously [4].

AIM

A dosimetric analysis of I-125, Pd-103 and Cs-131 brachytherapy seeds as well as radioactive bone cements loaded by uniformly distributed P-32, Y-90 and Ho-166 radioisotopes, was performed using Geant4 Monte Carlo toolkit and the corresponding dose distributions in the vertebral body and the spinal cord were obtained and compared with each other.

METHOD

Ten CT scan slices (with 6 mm thickness) of a normal spinal case (obtained from Imam Hossein Hospital, Tehran) were imported in Geant4 v6.10. One thoracic vertebral body was determined to be the tumor location. The whole vertebral body was considered as the gross tumor volume. In the case of vertebroplasty, a cylinder with 14 mm in radius and 6 mm in height, composed of PMMA was simulated in the vertebral body as the bone cement. This cylinder was cut with a smaller cylindrical section with a radius of 7 mm to make an offset region for the spinal canal. Three simulations were performed with P-32, Y-90, and Ho-166 uniformly distributed in the bone cement.

In the case of brachytherapy, the structure of the Amersham model 6711 seed [5] was simulated. The outer surface of the core was uniformly coated by low energy I-125, Pd-103, and Cs-131 radioisotopes in the simulation. Thirty seeds were placed in the vertebral body in three CT slices with the 8-10 mm inter-seed spaces (on each plane) and at least 7 mm distance from the spinal cord. A cubic mesh with the same resolution of the CT images (512×512 pixels) was defined to calculate the deposited dose in the voxels. The minimum dose delivered to 95% of the VB (D95%) was determined as the referenced dose for each radioisotope's radiation field. The tumor and the spinal cord were segmented using MATLAB 2015a code and then dose-volume histograms (DVHs) were obtained.

RESULTS

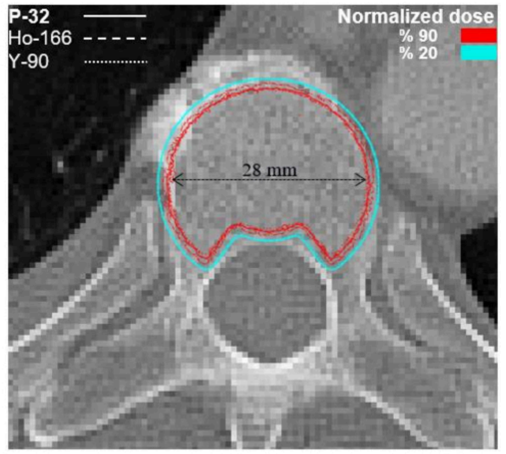

Fig. 1-a

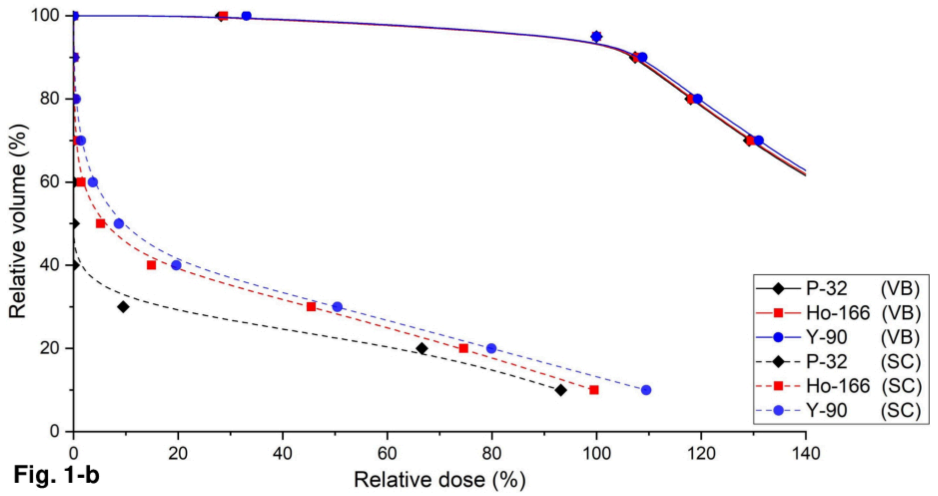

Fig. 1-b

Fig.1 (a) Normalized isodose contours in the central CT slice for radioactive bone cement in the case of vertebroplasty and (b) The corresponding DVHs of the VB and the SC

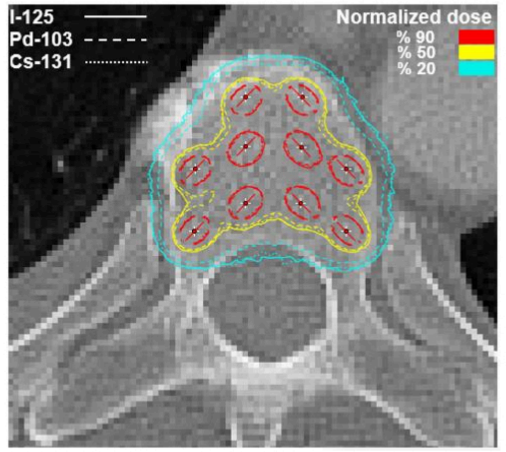

Fig. 2-a

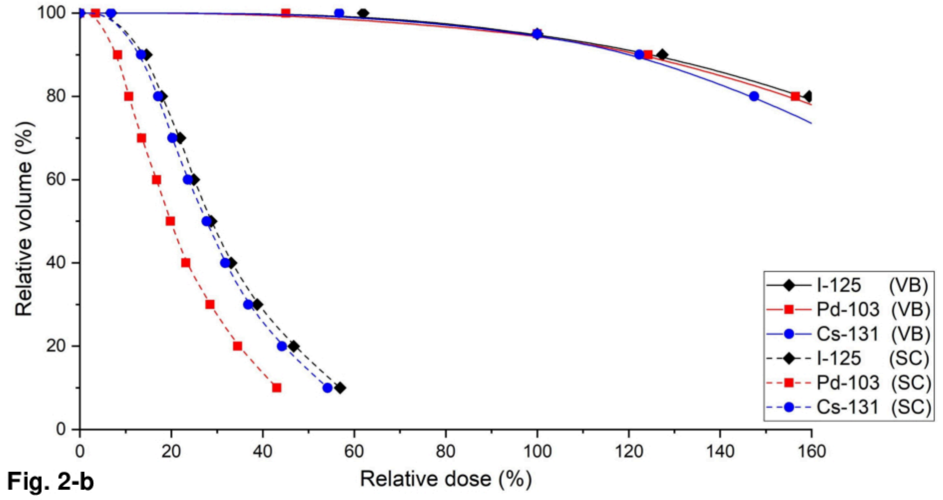

Fig. 2-b

Fig.2 (a) Normalized isodose contours in the central CT slice for) radioactive seeds in the case of brachytherapy and (b) The corresponding DVHs of the VB and the SC

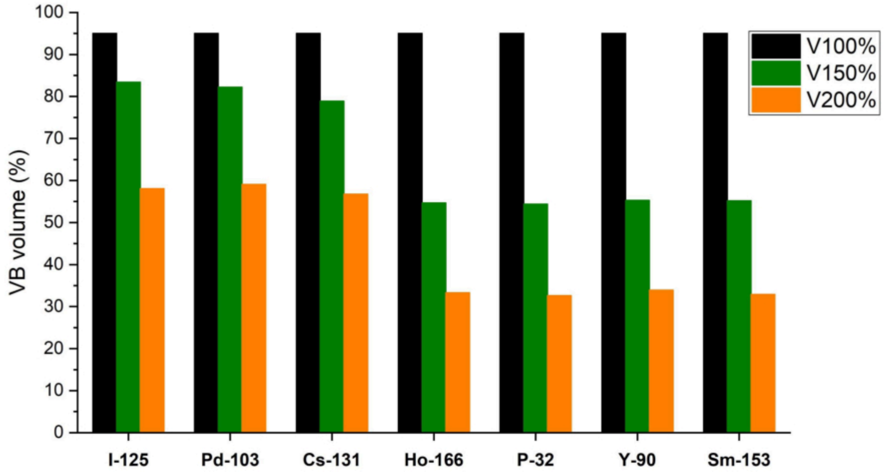

Fig. 3

Fig.3 V150% and V200% comparison for brachytherapy seeds and beta-emitting bone cements in the case of brachytherapy and vertebroplasty, respectively.

CONCLUSIONS

The concentricity and the distance between P-32 isodose curves were similar to those published by Kaneko et al. [6] since the dose decreases by 50% for every ~0.5 mm incremental distance from the surface of the bone cement.

Using brachytherapy seeds as the more penetrating sources are recommended for large tumors that fill the whole vertebral body and also for tumors that involve multiple vertebrae.

When the tumor is located in the posterior part of the vertebral body near the spinal cord , beta-emitting bone cement (preferably P-32) should be employed and it should be kept at least 4 mm from the spinal cord. Otherwise the aim of tissue sparing can be achieved by using Pd-103 seeds with more than 5 mm distance from the spinal cord.

It is recommended that I-125 (or Cs-131) seeds be implanted in the bone cement with at least 10 mm distance from the spinal cord.

ACKNOWLEDGEMENTS

The authors thank the staff of the Neurosurgery Unit at Imam-Hossain Hospital, Tehran, Iran.

REFERENCES

1 **Zuckerman SL et al**. Brachytherapy in Spinal Tumors: A Systematic Review. *World Neurosurg. 2018; 118:e235-44*

2 **Deramond H et al**. Percutaneous vertebroplasty with polymethylmethacrylate. Technique, indications, and results. *Radiol Clin North Am. 1998; 36(3):533-46*

3 **Kaneko TS et al**. Evaluation of a radiation transport modeling method for radioactive bone cement. *Phys Med Biol. 2010; 55(9):2451-63*

4 **Yang Z et al**. Treatment of metastatic spinal tumors by percutaneous vertebroplasty versus percutaneous vertebroplasty combined with interstitial implantation of 125I seeds. *Acta Radiol. 2009; 50(10):1142-8*

5 **Rivard MJ et al**. Update of AAPM Task Group No. 43 Report: A revised AAPM protocol for brachytherapy dose calculations. *Med Phys. 2004; 31(3):633-74*

6 **Kaneko TS et al**. Radioactive bone cement for the treatment of spinal metastases: a dosimetric analysis of simulated clinical scenarios. *Phys Med Biol. 2012; 57(13):4387-401*

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